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Araştırma

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Comparison of Three Different Color Doppler Techniques for the Assessment of Blooming in Venous Flow during Pregnancy

Gebelikte Venöz Akımda Blooming Artefaktının Değerlendirilmesi için Üç Farklı Renkli Doppler Tekniğinin Karşılaştırılması

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ABSTRACT

Aim: Blooming is an important color Doppler artifact for the assessment of small or slow-flow blood vessels during pregnancy. The degree of blooming varies depending on the color Doppler technique used. The purpose of our study is to compare doppler techniques related to the flowering artifact so that the imaging method closest to the actual size of small vessels can be selected.

Method: A total of 100 pregnant women were included in this study. The diameter of the intrahepatic umbilical vein was measured using three different color Doppler techniques: conventional color Doppler (CCD), power Doppler (PWD), and advanced dynamic flow (ADF). Blooming was assessed by comparing the diameter of the vessel in B-mode and in color Doppler mode.

Results: The diameter of the intrahepatic umbilical vein measured by ADF was smaller than that measured by CCD and PWD, indicating less blooming. The difference in diameter was statistically significant ($p < 0.05$).

Conclusion: ADF is a superior color Doppler technique for the assessment of blooming in venous flow during pregnancy, as it results in less blooming compared to CCD and PWD. This finding has important implications for the accurate assessment of small or slow-flow blood vessels during pregnancy.

Key Words: Color doppler ultrasonography, Artefacts, Pregnancy, Fetal ultrasonography, Vascularity

ÖZET

Amaç: Blooming, gebelik sırasında küçük veya yavaş akan kan damarlarının değerlendirilmesi için önemli bir renkli Doppler artefaktıdır. Çiçeklenme derecesi kullanılan renkli Doppler tekniğine göre değişir. Çalışmamızın amacı, küçük damarların gerçek boyutuna en yakın görüntüleme yönteminin seçilebilmesi için çiçeklenme artefaktı ile ilgili doppler tekniklerini karşılaştırmaktır.

Yöntem: Bu çalışmaya toplam 100 gebe dahil edildi. İntrahepatik göbek damarının çapı, üç farklı renkli Doppler tekniği kullanılarak ölçüldü: geleneksel renkli Doppler (CCD), güçlü Doppler (PWD) ve ileri dinamik akış (ADF). Blooming, damar çapının B modunda ve renkli Doppler modunda karşılaştırılmasıyla değerlendirildi.

Bulgular: ADF ile ölçülen intrahepatik umbilikal venin çapı, CCD ve PWD ile ölçülenden daha küçüktü, bu da daha az çiçeklenmeyi gösteriyor. Çaptaki fark istatistiksel olarak anlamlıydı ($p < 0.05$).

Sonuç: ADF, CCD ve PWD'ye kıyasla daha az çiçeklenme ile sonuçlandığı için gebelik sırasında venöz akışta çiçeklenmenin değerlendirilmesi için üstün bir renkli Doppler tekniğidir. Bu bulgunun hamilelik sırasında küçük veya yavaş akan kan damarlarının doğru değerlendirilmesi için önemli etkileri vardır.

Anahtar Kelimeler: Renkli doppler ultrasonografi, Artefaktlar, Gebelik, Fetal ultrasonografi, Vaskülarite

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Introduction

Blooming is a common color Doppler artifact that occurs when the color extends beyond the boundaries of a vessel, making it appear larger than its actual size [1,2]. This lack of lateral discrimination can lead to exaggerated or false positive vascular colorization, which can be a significant limitation for the visualization of vascular territories [1].

Advanced dynamic flow (ADF) uses a wide-band Doppler technique, while conventional color Doppler (CCD) employs narrow-band frequency transmission [3]. Power Doppler (PWD) is a variation of color flow imaging that displays intensity based on the sum of all Doppler shift frequencies, rather than on the mean Doppler shift as in color flow imaging [4].

In CCD and PWD, spatial resolution is low, and blood vessels may appear thicker than their actual size due to blooming, which can cause overlapping and difficulty in differentiating slow-flow blood vessels in the vicinity of a particular area in the fetus. In contrast, ADF with the wide-band Doppler technique can provide refined imaging of tiny vessels [5].

The aim of this study is to investigate and compare the blooming artifact in ADF, CCD, and PWD techniques. The results of this study may help to identify the best color Doppler technique for visualizing small or slow-flow blood vessels during fetal ultrasound examinations.

Material and Methods

Patients; Our study was conducted over a period of 2 months and included 100 patients who were referred to the Radiology Department of Antalya Training and Research Hospital for obstetric ultrasonography (US). The mean age of the individuals was 28.23 years (range: 18 to 43 years), with an average height of 1.62 meters (range: 1.50 to 1.75 meters) and an average weight of 62 kg (range: 45 to 118 kg). The average body mass index was 26.37 kg/m2 (range: 18.73 to 38.53 kg/m2). The mean gestational age based on the last menstrual period was 27 weeks (range: 15 weeks and 5 days to 40 weeks and 6 days), while the mean ultrasonographic gestational age was 27 weeks (range: 15 weeks and 4 days to 40 weeks). Measurements of the diameter of intrahepatic umbilical veins were obtained from all 100 fetuses by the same radiologist using a Toshiba diagnostic ultrasound system, Applio TUS-A500 (Toshiba Medical Systems Europe, Zoetermeer, Netherlands). Our study was approved by the institutional review board with the data usage permission numbered 24.03.2016/ 76/20, and written informed consent was obtained from all patients after a detailed explanation of the procedures they may undergo.

*Radiological Examination***:** In this study, the Twin-view Mode in Toshiba US systems was used to display monochrome and color images simultaneously in real-time. This mode allows for the simultaneous assessment and comparison of structural information in B-mode and hemodynamics in CCD or PWD. Intrahepatic umbilical veins were displayed longitudinally in Twin-view mode with B & CCD, B & ADF, and B & PWD modes in frozen magnified images for each of the three types of Doppler techniques. The vertical diameters of the veins were measured in the Doppler side and then in the B-mode next to the Doppler side at the same screen. This process was repeated for all three types of Doppler techniques by switching them consecutively. All of the Doppler US techniques' preset parameters were identical and had been created before the study started. The parameters were set as follows: dynamic range (DR) 70, dynamic frequency (DF) 3.0, color gains (CG) 30, color PRF 5, 9, and color filter (F) 4. The diameter of the vein was measured from the inner to the inner side of the vessels in the B-mode side and each colorized lateral side of the vessels in all of the Doppler modes (Figures 1, 2, 3). The diameters in each color Doppler technique minus the diameter of the grey-scale B-mode were calculated as the difference and named "delta."

Statistical Analyses: Continuous variables were summarized as average and standard deviations and categorical data were analyzed for frequency and percentage. Repeated Measures ANOVA and Bonferroni Post hoc tests were used for comparing techniques by diameter measurements. Intraclass correlation coefficients (ICC) were determined for checking the consistency of the calculated techniques. Statistical analyses were performed for multiple comparisons of the Doppler techniques for all parameters with SPSS v.22 and the level of statistical significance was set as 0.05.

Results

The study included 100 patients with a mean age of 28.23 years, a mean height of 1.62 m, and a mean weight of 62.62 kg. The patients had a mean gestational age of 27 weeks, with a range of 15 weeks 4 days to 40 weeks. The diameter measurements of the intrahepatic umbilical veins were obtained using three different Doppler techniques: ADF, CCD, and PWD.

The results of the study showed that there were significant differences in the diameter measurements obtained by the three techniques. The ADF technique produced smaller diameter measurements (4.660 mm ± 1.448) compared to CCD (6.984 mm ± 1.883) and PWD (6.857 mm ± 2.259). When comparing the delta values of the techniques with the B mode, ADF had significantly smaller delta values compared to CCD and PWD. CCD and PWD had similar

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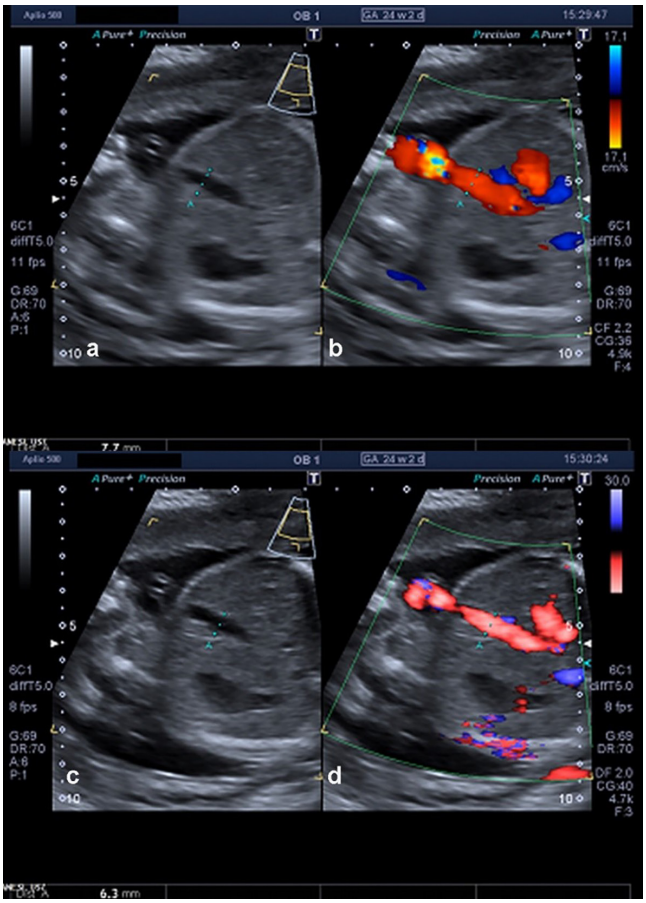

Figure 1. (a) Twin-view with CCD technique image of vessel diameter measurement from B mode side. (b) Twin-view with CCD technique image of vessel diameter measurement from CCD Doppler side. (c) Twin-view with ADF technique image of vessel diameter measurement from B mode side. (d) Twin-view with ADF technique image of vessel diameter measurement from ADF Doppler side.

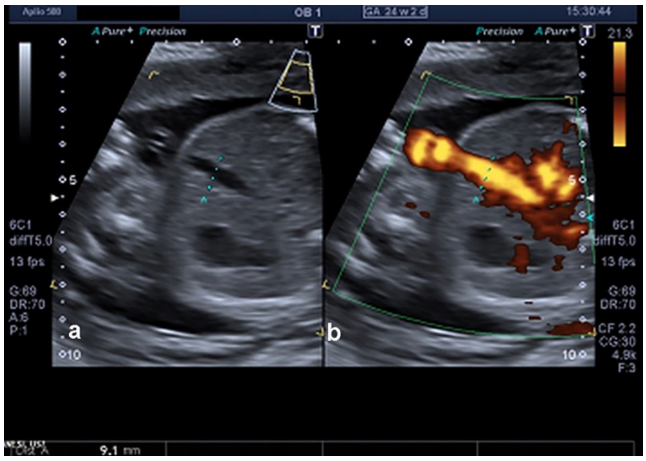

Figure 2. (a) Twin-view with PWD technique image of vessel diameter measurement from B mode side. (b) Twin-view with PWD technique image of vessel diameter measurement from PWD Doppler side.

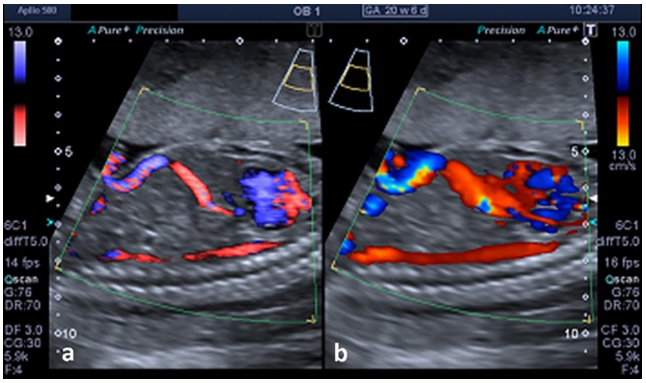

Figure 3. Imaging of the umbilical vein and the ductus venosus with (a) ADF and (b) CCD technique in a 14 weeks 5 days pregnant patient.

delta values (Table 1). This suggests that CCD and PWD techniques overestimate the diameter measurements due to blooming artefacts, while ADF technique measures the diameters closer to the gray-scale.

The study also found that the consistency of the color Doppler technique and gray-scale was highest with ADF, followed by PWD and CCD. The differences between CCD and PWD were not statistically significant, and both techniques overestimated the diameters similarly due to the similar blooming effects.

Intraclass correlation coefficients (ICC) were calculated to check the consistency of the techniques, and the results showed that ADF had the highest ICC value (0.964), followed by PWD (0.947) and CCD (0.882). These values indicate good consistency among the measurements obtained by the different techniques (Table 2 and Table 3).

Table 1. Comparisons of B mode and the Doppler techniques

	Mean	Std. Deviation	N
Delta CCD	2,371	1,253	99
Delta ADF	0,091	0,619	99
Delta PWD	2,134	1,414	99

CCD: Conventional Color Doppler, ADF: Advanced Dynamic Flow, PWD: Power Doppler

Table 2. Consistency of the Doppler techniques

	Intraclass Correlation[b]	95% Confidence Interval	
		Lower Bound	Upper Bound
Single Measures	0,786[a]	0,716	0,843

All color Doppler techniques' consistency was well (ICC= 0,786 and 95 % GA=0,716-0,843).

Table 3. Consistency of the Doppler techniques in gray-scale mode

	Intraclass Correlation[b]	95% Confidence Interval	
		Lower Bound	Upper Bound
Single Measures	0,921[a]	0,891	0,943

All color Doppler techniques' consistency in gray-scale was quite well (ICC=0,921 and 95 % GA=0,891 – 0,943).

Overall, the study suggests that ADF technique may provide more accurate diameter measurements of the intrahepatic umbilical veins compared to CCD and PWD techniques, due to less blooming artefacts.

Discussion

The techniques of Doppler ultrasound have been available to clinicians for nearly 40 years [4]. CCD and PWD are used to guide the mapping of the vascular tree in the body, including fetal parts. Users of Doppler ultrasound techniques must be aware of the complicated aspects of flow in the body [2]. The pulse Doppler (PD) sampling gate is placed in the vascular bed with the guidance of CCD or sometimes with PWD. However, both techniques have limitations such as blooming and color scatters off the vessel wall.

ADF was announced in April 2001 with Toshiba's Applio diagnostic ultrasound systems. Even though ADF has been available for more than a decade, its efficacy and capabilities in fetal Doppler examinations are not well understood amongst Doppler ultrasound examiners. The aim is to objectively compare ADF, CCD, and PWD techniques, independent of the manufacturer of Toshiba Medical.

CCD imaging uses a long burst pulse, which means it employs narrow-band frequency transmission. In contrast, ADF uses a short pulse, which is similar to B-mode imaging, and wide-band transmission. This is the fundamental principle of wide-band Doppler technology (Figure 1) [5].

Blooming is particularly important in the case of the tiny or slow-flow blood vessels of the fetus. Blooming can increase false vascularity and also lead to incorrect sampling in PD. Lowering the Doppler gain can reduce the blooming artifact, but this may also result in the loss of flow information. Conversely, raising the gain can overestimate the vessel diameter or over-colorize the tissue or mass in terms of vascularity.

The potential for misdiagnosis due to blooming artefacts is particularly concerning in inexperienced hands, as it can lead to prolonged examination times and unsatisfactory color guiding for visualizing small vessels such as the ductus venosus and middle cerebral artery in fetuses. In some cases, accurate vascular colorization is crucial for correct placement of a PD sampling gate and to obtain reproducible measurements, especially when investigating structures like the ductus venosus in fetuses between 11 and 14 weeks. Blooming can also prevent the depiction of vascular borders in close proximity to other structures, such as the ductus venosus, middle cerebral artery in the circle of Willis, and fetal renal arteries. This can be especially problematic in spectral pulsed Doppler techniques, leading to misinterpretation of findings and decreased diagnostic accuracy. [6].

The study aimed to compare the blooming effects and accuracy of vessel diameter measurement between ADF, CCD, and PWD techniques in Doppler ultrasound examinations using the intrahepatic umbilical vein. The study did not aim to establish normal reference values for the diameter of the intrahepatic umbilical vein.

The results of the study suggest that ADF is a more effective technique than CCD and PWD in terms of reducing blooming and improving visualization of the actual lumen of vessels. This improved visualization can lead to better accuracy in determining vessel diameter, as well as easier visualization of small vessels and improved placement of PD sampling gates. Overall, the study supports the use of ADF as a preferred technique in PD examinations. The improved visualization of the lumen enables easier detection of small vessels, accurate placement of the sampling gate, and clearer spectral analysis [7].

The usefulness of the ADF Doppler technique with regard to less blooming for evaluating fetal vasculature, which was statistically proven, has not been reported previously to the best of our knowledge.

Despite the apparent advantages of ADF for vascular mapping, it has not been widely used in Doppler US examinations worldwide. In an incomprehensible manner, ADF applications have not been well studied in the medical literature, as can be seen by the limited number of references available on the topic.

There are some limitations to using the ADF technique, such as the inability to detect turbulences as well as CCD can. However, this limitation can be overcome by adjusting the color encoding preset according to the user's preference or by combining both techniques. For instance, the ADF can be used initially for accurate vascular mapping, followed by CCD to determine turbulence in the ductus venosus for sampling gate placement before spectral analysis.

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The decreased blooming artefact in vascular mapping in fetuses has several benefits. Firstly, it allows for easier visualization of the ductus venosus even by inexperienced sonographers, thereby reducing the number of unsuccessful examinations and the need for supervised training. Maiz et al. [8,9] found that at least 80 exams are needed for successful ductus venosus examination under supervised training, which can potentially be reduced with the use of ADF technique. Secondly, the reduced blooming artefact decreases contamination from neighboring vessels in spectral analysis, potentially leading to more reproducible and reliable spectral waveforms for accurate diagnosis. Finally, congenital vascular variations or displaced vessels due to intrauterine malformations, such as diaphragmatic hernia, can be more easily visualized and assessed with ADF Doppler technique.

Conclusion: The ADF Doppler technique is a promising tool for evaluating fetal vasculature with less blooming and higher resolution compared to CCD and PWD techniques. Its benefits include easier visualization of small vessels, correct sampling gate placement, clearer spectral analysis, and less contamination from neighboring vessels in spectral analysis. However, the technique's limitations include decreased ability to detect turbulence and limited availability in current clinical practice. Further research is needed to define the potential applications of ADF not only in prenatal examinations but also in adults.

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